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3. Human Refuse as a Major Ecological Factor in Medieval Urban Vertebrate Communities

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Organic refuse, such as food and butchery waste, was commonly deposited in dumps and pits in medieval towns throughout northern Europe. These deposits of refuse attracted and supported a diverse community of scavengers and their predators. The organic refuse can be seen as a source of energy that maintained food-webs of donor-controlled populations, giving them potentially high population densities, founder-controlled response to perturbation, and perhaps a strongly stochastic element in determining which species became dominant at any particular location. The red kite is an example of a scavenger which was strongly dependent on refuse deposition, and it is argued that cats in medieval towns may have lived largely as predators within the refuse-supported food-webs.

Keywords: TOWNS; ORGANIC REFUSE; SCAVENGERS; FOOD WEBS.

INTRODUCTION

This paper reviews the importance of organic refuse disposed of by humans as a major factor in the character of vertebrate communities in early towns. The topic has developed out of the author's interest in early medieval towns in England, and in birds in particular, and the discussion somewhat reflects those interests. The paper does not set out to give definitive answers or to present new data. Rather, the aim is to look at a familiar context in a different way, and to derive from that altered paradigm a series of postulations and questions for further research.

The initial premise is that one of the characteristics of the early stages of urban development in European towns was an unorganised approach to refuse disposal. Note here that I am dealing with all categories of organic refuse, not just faecal matter and other *sewage*, but particularly bones, meat and offal waste, and waste plant materials of all kinds. Separated from fields and livestock, people could not readily utilise garbage as manure, leading them to deposit waste organic material onto vacant patches of ground, into pits, and, presumably, into watercourses. This last form of disposal takes the garbage beyond the remit of the present paper, though it may have been of some importance in wider ecological terms.

The archaeological evidence for disorganised refuse disposal is clear to see. Many sites in early medieval towns have been characterised by thicknesses of dark, humic material, which on analysis appears to have been deposited as plant and animal debris of diverse kinds. Such deposits are familiar enough from towns such as London, York, Newcastle, Dublin, Bergen, Oslo, and Amsterdam, and they have been the focus of much published research (e.g. Schia 1988; Vince 1991; Kenward and Hall 1995). In terms of the archaeology of the towns, we tend to think of these deposits as a source of valuable data on plant remains and, particularly, invertebrate animals, and as a feature in the day-to-day environment of the people that lived in the medieval towns.

In terms of the ecology of those towns, the refuse deposits constituted a concentration of energy and nutrients, which supported a community of detritivores, scavengers, and their respective predators, and that will be the approach taken by this paper. The refuse is seen as energy for life, and my concern is with the characteristics of distribution of that energy, and the consequences for the communities which subsisted upon it. Again, there is ample archaeological evidence of these communities and of the vertebrate and invertebrate species involved. Work in York and Oslo, for example, has produced volumes of data on invertebrates and vertebrates which form this community, feeding either directly on decaying organic material, or on moulds and other fungi which grew on the organic refuse, or on other animals that did so.

DONOR-CONTROLLED FOOD WEBS

Figure 3.1 gives a very simple form of food web to show the part played by organic refuse, and is organised at the level of guild, rather than species, for reasons which will become clear in due course. Figure 3.1 is principally concerned with animals: the role of saprophytic fungi is not explicitly acknowledged, but should not be disregarded. In such a community, rates of population growth and eventual population densities are freed from the familiar interactions of predators and prey, typical of Lotka-Volterra type models of population change. The prey at the lowest trophic level is the organic detritus, and whilst the availability of that detritus controls the populations of the taxa which feed upon it, there is no feedback loop – the prey (refuse) controls the density of the recipient (detritivore, predator) but not the reverse. The prey population is controlled by the rate at which it is donated from outside the food-web. Such food-webs are thus controlled from the bottom upwards, and are often referred to as *donor controlled* (Pimm 1982). In other donor-controlled systems, such as in the decomposer community of woodland leaf-litter, there is some feedback, in that decomposers will liberate nutrients to the benefit of the trees, thus possibly increasing the amount of leaf growth and subsequent leaf litter. However, in the context of urban refuse, such feedback pathways are unlikely to have been significant: the activities of the woodlice in one's backyard has little effect on one's generation or disposal of refuse. The bottom-up model is important from an archaeological point of view, because it means that the nature and intensity of human activities, and thus the activities with which archaeology is primarily concerned, has a direct bearing on the energy input to the refuse ecosystem.

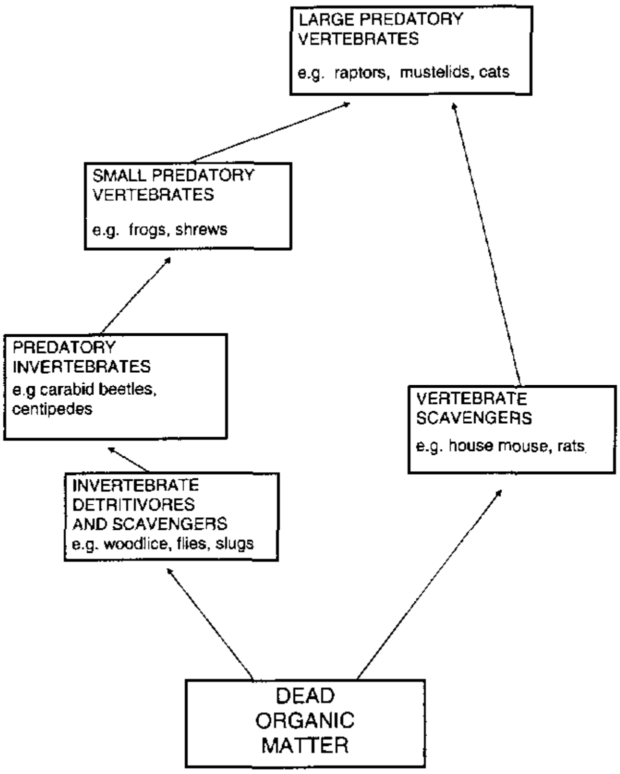

Figure 3.1 Simplified diagram of a food-web supported by dead organic matter (i.e. organic refuse), showing the major guilds in such a food-web and the taxa that might be typical of each guild.

Of course it follows that there will also have been plants growing within medieval towns, generating gross primary productivity (GPP), and supporting primary consumers, and so on. Some plants will have grown upon old refuse deposits, utilising nutrients released in the decomposing refuse, and adding another energy source to the ecosystem. Figure 3.2 shows the relationship between the food-web supported mainly from GPP, and that supported mainly from dead organic matter (DOM). Presumably, as a refuse deposit ages and decays, especially as and when pedogenesis begins and so facilitates colonisation by plants, there is an increase in the importance of the GPP-supported food-web in terms of energy flux. However, it is my contention that organic refuse will have been the more significant source of energy, at least in the early stages of build-up and decay of a refuse deposit. Given that refuse deposition events may have been frequent and short-lived, it is the early stages of community development that may be the most interesting to us. Clearly, there will have been some movement of generalist taxa between GPP-supported and DOM-supported food-webs, so the division between the two is somewhat artificial, but none the less clear enough to allow us to postulate the existence of a DOM-supported food-web, with a predominantly donor-controlled community.

Donor-controlled communities show a number of distinctive characteristics. One of the best known is that the population densities of species in those communities can rise to levels much higher than would be typical of the same species living in other ecosystems. As a mundane example, consider the street pigeon *Columba livia*. When in donor-controlled systems, dependent on human refuse and direct feeding, pigeons live at population densities orders of magnitude greater than are characteristic of free-living rock dove, which is conspecific. Less dramatically, Erz (1966) shows that urban

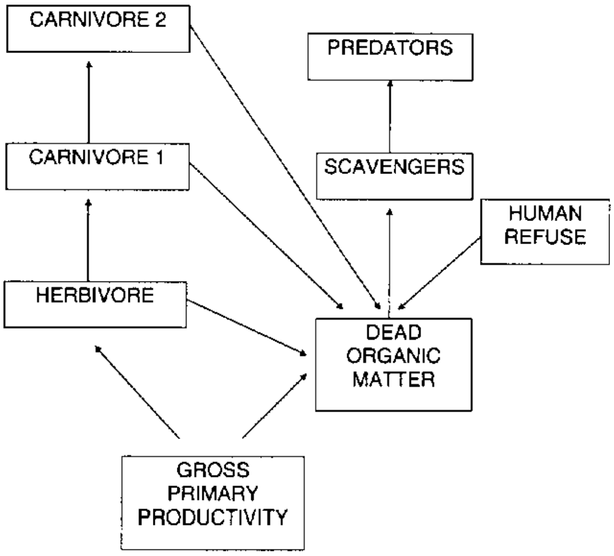

Figure 3.2 As a refuse deposit ages and humifies, pedogenesis and the colonisation of the weathered surface by plants would lead to the development of a trophic structure based on the green plants and their photosynthetic product, with taxa in that food-chain contributing corpses and faeces to the dead organic matter component.

blackbirds *Turdus merula* nest at about twice the density of their rural compatriots, and live longer. Whereas pigeons probably feed fairly directly on the refuse of human settlement, at least some of the advantage gained by urban blackbirds may be through exploiting high densities of invertebrate animals, themselves supported by organic refuse. Frogs, too, are often very abundant in urban deposits, and we sometimes spend time and ingenuity trying to think of good explanations (e.g. O'Connor 1988, 113–4). Maybe the best explanation is the simplest: lots of refuse, so lots of flies, so lots of frogs. One of the many questions which this paper leaves unanswered is what ate the frogs? Perhaps nothing did, at least not in sufficient numbers to have a substantial impact, and that is why we recover such quantities of more or less intact adult frog bones from soil samples.

Another feature of donor-controlled communities is that empirical evidence and theoretical models suggest them to be inherently stable. Much of our understanding of community stability is based on food-web models which assume top-down feedback from predators to prey. In these systems, increased species diversity and food-web complexity (actually connectance) tends to decrease the stability of the food-web. Theoretical modelling of food-webs suggests that donor-controlled systems are not destabilised by an increase in diversity or complexity (Pimm 1984). In other words, although food-web theory has yet to deal with donor-controlled systems in anything like the detail with which it has explored other systems, it appears that stability may be one of their distinctive attributes. The communities living on and around refuse deposits may therefore have included species at much higher population densities than we would expect from modern observation, and the food-webs involved may have been both complex (with high species diversity and high connectance) and stable, a combination unusual in systems in which top-down feedback predominates (see also Winder, this volume).

DEVELOPMENT OF DONOR-CONTROLLED COMMUNITIES

There are important questions to consider regarding the creation of these refuse patches in the first place. The availability of refuse to drive the ecosystem required human decision-making, and people have a great tendency to change their minds. Particular places must quite suddenly have become places of refuse disposal, and just as suddenly ceased to be one. When people began to dump rubbish in a particular place, how did the community develop? We can postulate that some species would have been more successful colonisers than others (small bodies, mobile, rapid breeders etc – good news for spiders and shrews!), but when patches of habitat are coming and going fairly rapidly, there is a strong stochastic element involved. One of the reasons for setting out Fig. 3.1 in terms of guilds is to make the point that a given refuse patch may have created a vacancy for a particular sort of animal, occupying a particular niche, but the species by which that guild was represented may have had more to do with chance and the distance to the nearest source population. Furthermore, we only poorly understand the assembly rules for such a community, if at all. Because our observations of modern habitats are more often snapshots than longitudinal studies, we often have only a poor idea about the detail of the competitive interactions which take place during the early stages of colonisation, as space and niches are occupied by early colonisers, so reducing the chances of successful colonisation by later arrivals.

For example, one of the more puzzling differences between the range of vertebrates recorded from medieval deposits in York and in Beverley is the paucity of raven *Corvus corax* in the latter. This was first noted by Sally Scott in the mid-1980s, when she realised that she was finding no raven bones in Beverley samples, whilst I was finding the species regularly in York material of about the same date which was being sorted and recorded in the same way, in the same laboratory, at the same time. For example, in 12–13th century refuse deposits from Coppergate, York, we have raven in 10 out of 18 contexts: it is the third most frequent non-domestic bird taxon after mallard and small goose (Bond and O'Connor 1998). At Eastgate, Beverley, there were no specimens of raven in over 19000 identifiable bones, despite there being 24 other bird taxa recorded (Scott 1992). And Lurk Lane lacked raven from an even larger assemblage, with a similar diversity of birds (Scott 1991). The absence of the species from Beverley was about as definite as absences can ever be.

We tried to come up with a plausible explanation in terms of the environment in and around the two towns, and wondered whether there was less mature woodland around Beverley in the medieval period, and thus less available roosting and nesting habitat. As Scott put it:

> "Raven is perhaps the most commonly recovered scavenging bird from medieval urban sites. Its absence from Eastgate serves to emphasise the conclusions drawn from the Lurk Lane assemblage, where raven was also unrepresented; i.e. that there may have been an absence of mature woodland habitat ... around Beverley by the time of the Conquest." (Scott 1992, 246).

That suggestion was roundly criticised by Barbara West (*in litt.*), and in retrospect I think she was right. Maybe the absence of raven at Beverley had to do with colonisation, and the exclusion of one species by an earlier arrival. In other words, both towns had a big scavenger bird guild, but in Beverley other species in that guild – other corvids, kites – arrived first and established populations quickly, and so prevented raven from colonising the town. Perhaps the only difference between the towns was the largely stochastic question of how quickly ravens arrived, and what we are seeing in the data is a hint of assembly rules. We did not reach this conclusion ten years ago because we were looking at the data as a static snapshot of the fauna and hence the environment of the two towns.

COLONISATION, PERTURBATION AND PATCHINESS

There are other questions that might be discussed. For example, did the colonisation of towns, and the establishment of refuse-maintained communities, follow island-like rules, and an equilibrium model? This is a topic which Harry Kenward (1997) has explored with particular reference to beetles, showing that at least some of the implications of the classic equilibrium model of island biogeography (MacArthur and Wilson 1967) can be applied to islands of past human occupation. There is clearly scope for widening the question beyond beetles to encompass whole communities, though that is well beyond the remit of this paper.

And what about the general level of perturbation of such communities? Presumably the consequences of regular deposition of refuse during the life of a rubbish dump constituted low-level perturbation, partly through the disturbance inherent in deposition of new material, but also in a more subtle way through the addition of material perhaps less decayed and degraded than that already in place, so increasing habitat diversity within the patch.

The effects of perturbation are intriguing. At a low level of perturbation, a resilient community may quickly resume much the same equilibrium state, whereas high levels of perturbation will inhibit successional development of a community, leading to low species diversity and a predominance of coloniser species (Putman 1994, 122–3). At an intermediate level, however, perturbation may enhance species diversity, in part by enhancing habitat diversity, and in part by mitigating the consequences of inter-species competition, which might otherwise lead to the local extinction of the less competitive species. If repeated disturbance opens up gaps, either physical or behavioural, which always tend to be colonised by the same one or two dominant species, the community may be described as *dominance-controlled* (Yodzis 1986). Conversely, if the gaps are colonised by different species following successive disturbance events, and those species successfully hold the colonised space, then the term *founder-controlled* may be applied. Given that I have argued that the colonisation of refuse dumps may have been highly stochastic, it is unlikely that the communities that developed were dominance-controlled. Founder-controlled communities have the important characteristic that they can develop and maintain high species diversity (Begon *et al.* 1990, 761–6; Winder this volume), so we have another reason for expecting the DOM-supported food-web to show high species diversity.

Patchiness of habitat may have had effects of its own. Modelling of competitive effects when the habitat is very patchy, forcing populations into localised aggregations, suggest that species that are poor competitors in a more homogeneous environment may be more successful when that environment is patchy (Atkinson & Shorrocks 1981; Begon *et al.* 1990, 256–7). The models seem to show that the enforced aggregation of populations leads the more effective competitors to use more of their energy in within-species competition, and so less in competition with less competitive species. Real empirical data are lacking here, but the possibility is an interesting one, perhaps leading to unexpected patterns of relative abundance in archaeological material.

FOOD-WEB COLLAPSE AND SPECIES EXTINCTIONS

So much for colonisation, and the characteristics of the DOM-supported food-web. But what happens if people stop donating refuse? The food web collapses, and a number of species either go locally extinct, or face a rapid change of niche, or suffer a drop in population density to that which the new conditions will maintain. In those circumstances, the selective advantage is definitely with the less specialised taxa, and with those that can recover most rapidly from a population crash. Large-bodied specialists are the ones most likely to have gone locally extinct.

Consider the red kite *Milvus milvus*. This was once a common bird in English towns. The *Hortus sanitatis*, a medical treatise printed in the late 1480s, includes a kite apparently perched on a man's head in an illustration which purports to show a typical street scene. In 1496–7, the Venetian Ambassador, Signor Capello, passed the winter in London, and was astounded by the abundance of scavengers in London (Gurney 1921, 82). He mentions crows, jackdaws, and ravens (all familiar from archaeological material), and gives special mention of kites, apparently so tame that they would take bread from the hands of little children. What would today's parents make of that? Capello observes that ravens and kites were protected by law from destruction, "as they say that they keep the streets of towns free from all filth". Another reference to protection comes from William Turner (later Dean of Wells) in 1555. Turner swiftly condemns predatory birds such as harriers, which interfere with wildfowl that might be taken for sport, but reiterates Capello's point about kites being abundant, audacious, and protected.

By a century later, the time of such natural historians as Willughby, John Ray and John Evelyn, urban kites are no longer mentioned. It seems there was a problem with kite populations around this time, and the population crash which was to lead to their extinction as an urban bird in northern Europe was underway. Writers such as Edlin (1952) are inclined to equate this with the general reduction of predators at the hands of game-keepers, that suddenly kites were seen as a nuisance to be exterminated. There is no good evidence for including urban kites in this extermination, and the cause of their demise may have been much simpler.

It might have been a consequence of the more efficient organisation of the disposal of urban refuse. Towards the end of the medieval period, and on into Tudor times, the archaeological record commonly shows a reduction in the amount of refuse being deposited in unoccupied corners of towns and in hastily-dug pits, with substantial stone-lined cess-pits which could be cleaned out becoming more common. Although Sabine (1937) attributes an increase in cleanliness to the late 14th century, he is describing only London, and mainly talking about the disposal of faecal matter, not more general urban debris. The archaeological record would suggest that in most towns, the disposal of organic refuse included surface accumulations into the post-medieval period.

The continued success of the black kite *Milvus migrans* as an urban bird in the Indian subcontinent can probably be attributed to the relatively recent development of systematic refuse disposal in cities in that region, plus, of course, the more common availability of human remains in places where sky-burial is practised. The very high population density of black kite in Delhi reported by Galushin (commonly 10–15 km^{-2}, Galushin 1971) underlines the point above about the high population densities which donor-controlled systems can support. It seems quite reasonable to suppose that medieval towns in northwestern Europe supported similar population densities of red kites.

So perhaps red kite serves as a good example of a species which benefited considerably from disorganised refuse disposal, and suffered badly when that practise ceased. One wonders what other species were affected to a less obvious extent. Invertebrates are beyond the brief of this paper, but it would be interesting to model which arthropod species might have been the ones most likely to have built up very high population densities at times of plentiful refuse, either directly or as predators of others, and so which might have been most affected when that supply was interrupted. Maybe there is even enough archaeological data to begin to test those speculations?

And what about the top predators? It is an open question, I think, whether cats in 9–12th century towns in northern Europe existed as maintained companion animals, as today, or as free-living commensal populations. McCormick (1997) has argued that the abundance and age at death of cats from urban sites in Ireland is consistent with the deliberate breeding of cats for their fur, and it is certainly true that knife-cuts consistent with skinning can often be seen on cat bones from medieval towns. However, the use of cat fur need not imply the deliberate breeding of cats; not if there were substantial free-living populations to be cropped when necessary. The relatively high frequency of sub-adult bones in urban cat samples is consistent with free-living populations, particularly as

	Early 4–8mo	Middle 8–14mo	Late 14–20mo
Late medieval York	100	73	56
Late medieval Lincoln	67	35	43
Medieval Exeter	98	49	40
Post-medieval Exeter	70	58	47
Medieval Cambridge	59	25	13
Medieval Dublin	93	35	51
Medieval Waterford	100	53	43

Early – distal humerus, proximal radius

Middle – Proximal femur, distal metapodials, proximal ulna, distal tibia

Late – proximal tibia, distal femur, distal radius, proximal humerus

Table 3.1 Epiphysial fusion in samples of cat bones from a number of urban sites in Britain and Ireland. The figures shown are the percentage of epiphyses in each group which were fused, and give an approximation to the proportion of individuals which survived beyond the age at which that group of epiphyses fused. The age brackets are somewhat approximate. Data are from O'Connor (1992, 110–2), McCormick (1997), and Luff and Moreno-Garcia (1995).

the age groups represented tend not to include the very youngest, but the adolescent cats which would have been leaving parental care – the vulnerable time of life for feral cats today (O'Connor 1992). Table 3.1 summarises epiphysial fusion in medieval cats from urban sites in Britain and Ireland, showing the often low proportion that survived beyond a year or so old. In the refuse-supported food-web which is postulated here, cats would be one of the top predators, benefiting in terms of population density from the dense prey populations. What was the effect of more organised refuse disposal? A preliminary review of the literature failed to locate enough data to show whether post-medieval samples of cats show a distinctly different mortality profile, but a more focussed study might look at that question in detail.

CONCLUSION

To sum up, the refuse generated by people was trophically important, and localised both in time and space. Furthermore, the communities supported by these refuse deposits are likely to have had very distinctive characteristics. I would argue, therefore, that peoples' attitudes to and disposal of their refuse, in which there is obviously a strong cultural component, would have had a major effect on the animal communities living in early towns, both in terms of colonisation by, and local extinction of, different species, and in terms of the population densities attained by some species, and so their potential visibility in the archaeological record. The challenge for us is to model these communities, and their dynamics and structure, and to move the discussion of urban faunal lists away from the presence or absence of particular indicator species or species associations and their significance in terms of habitat. The world just isn't that simple, and there are much more interesting questions which we should be asking.

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